UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

FOREST INSECT INVESTIGATIONS

A PROGRESS REPORT ON THE BIOLOGY AND CONTROL OF THE HEMLOCK BORER, *Melanophila fulvoguttata* (Harr.) IN EASTERN HEMLOCK - Project h-1-3 (1) in 1939

by

H. C. Secrest

Forest Insect Laboratory
Milwaukee, Wisconsin
April 6, 1940

U. S. GOVERNMENT PRINTING OFFICE 60918

A PROGRESS REPORT ON

THE BIOLOGY AND CONTROL OF THE

HEMLOCK BORER, *Melanophila fulvoguttata* (Harr.)

IN EASTERN HEMLOCK - Project h-1-3 (1)

in 1939

by

H. C. Secrest

Forest Insect Laboratory
Milwaukee, Wisconsin.
April 6, 1940

TABLE OF CONTENTS

INTRODUCTION

At the request of the Indian Service, U. S. Department of the Interior, an investigation of the hemlock borer infestation on the Menominee Indian Reservation was begun in 1937 by L. E. Yeager, and a report on the survey of conditions was submitted in December of that year.

Following Yeager's resignation in June 1938 the project was continued by the writer, and a report of the 1938 studies was submitted in March 1939. Both the 1938 and 1939 studies were directed toward the accumulation of biological and physiological data, as no previous detailed studies had been made of the eastern hemlock borer Melanophila fulvoguttata (Harr.). The 1939 studies, however, were directed primarily toward a more intensive investigation of those phases which gave promise of showing conclusively whether the hemlock borer was to be considered a secondary insect in the stands of the Menominee Indian Reservation.

BIOLOGICAL STUDIES

Winter Mortality

The winter mortality of the hemlock borer for 1938-1939 was determined by making bimonthly examinations. In material affording the larvae a favorable habitat the mortality was very low, never exceeding 10 percent.

Length of Life Cycle

During the summer of 1939 periodic observations were made of the 9 cut trees in the tree-condition study which was established in June 1938. These trees, which were were apparently borer-free when felled and caged prior to the 1938 beetle flight, had been artificially infested on June 23, 1938, by introducing 30 field-collected beetles (20 females and 10 males) into each cage. With but one exception, 1939 beetle emergence occurred from all of the caged sections. Peeling of this excepted section showed successful larval attack, but for some undetermined reason the larvae had failed to mature. Beetle emergence resulting from ovipositions on the uncaged portion of the trees also occurred in 1939. (Fig. 1.)

Borer pupae were found in the bark of these trees during the second week in July 1939. The greater part of the emergence occurred the latter half of the month and the remainder in August. No emergence holes were found in the examination of July 18. Practically all the 1939 beetle emergence from these trees was confined to the upper surface of the caged sections and the greater part to that portion at the top of the log. The bark of two of the caged sections was carefully peeled

in October 1939, and, as was expected inasmuch as the trees were felled before oviposition occurred, the majority of the ovipositions were found on the upper surface of the tree trunks. However, a number of larvae were also found on the lower and side surfaces of the logs, and these larvae were mature, apparently healthy, and resting in cells in the bark. Practically no beetle emergence had occurred from these portions. These larvae obviously will have a 2-year life cycle and will emerge as adults in 1940.

Since all these ovipositions occurred at approximately the same time, this difference in the length of the life cycle indicates that the hemlock borer larvae are apparently highly sensitive to environmental conditions. The exact factors responsible are not positively known, but it seems logical to assume that heat from direct sunlight is directly responsible or, through its influence on moisture content and possibly certain physiological processes of the cambium, is indirectly responsible for considerable variation in the life cycle.

This season's observations furnished evidence that substantiates the theory, previously advanced, that larvae from late summer (August) ovipositions have a 2-year life cycle. Two trees which were windthrown late in July 1938 and were not successfully attacked until after that date were examined in December 1938 and in May 1939 and found to contain only small borer larvae. A 10-foot linear section of the trunk of each tree was caged in May before the appearance of the beetles. The larvae in these trees were mature and in the bark in August, but pupation had not occurred. These larvae will doubtless pupate and emerge next season, thus completing a 2-year life cycle.

Relationship of Temperature to Time of Beetle Emergence

In April 1939 eight borer-infested trees were selected, numbered, and felled. The second and third logs of each tree were also numbered and oriented. The second log carried the tree number plus the letter "A" and was that portion between 20 and 36 feet of the bole length. The third log, from the bole immediately above the second log, was also 16 feet long and was given the tree number plus the letter "B". One log from each tree was decked under shade in an uncut stand and the other in the open in a burned-over area. The logs were divided, that is there were four "A" logs and four "B" logs in each deck, in order to have second and third logs in each deck, have all eight trees represented, and have the decks similar.

The rate of development of the borer population of the upper and lower surfaces of these logs was determined at intervals of approximately 1 week through the time the beetles were emerging, by taking bark samples approximately 1 square foot in area. These were peeled and chipped, and the development of all borers was noted. Emergence hole counts were made on all logs in the decks when the examinations were made, and each new hole was marked so that it would not be tallied a second time. (Table 1.) A difference of 2 weeks was common between the first beetle emergences in the upper and lower surfaces of the individual logs, and similar differences were observed in the beginning of pupation on these surfaces. A difference of 4 to 5 weeks was found between the peaks of beetle emergence from the upper and lower surfaces of the logs in the open deck . A similar difference of 2 to 3 weeks occurred for

the logs in the woods deck. On both surfaces the peaks of emergence in the open deck were 2 to 4 weeks earlier than those in the shaded deck. The peaks are underlined in table 1.

Several days were devoted to taking hourly measurements of the air temperature at the bark surface and the subcortical bark temperatures of the upper and lower surfaces of the logs in both decks. A portable potentiometer, equipped with a number of thermocouples and a multiple switch, was used to measure these temperatures. Information to explain the differences in rate of borer development was obtained in this study. During early June maximum differences of 75°F. at the bark surface and 36°F. in the subcortical bark were recorded for the upper and lower surfaces of the logs in the open deck. The maximum air temperatures at bark surface and for the subcortical bark of the upper surfaces of the open deck logs were 140°F. and 100°F. respectively. In late May the maximum differences in air temperature at the bark surface between the upper and lower surfaces of the open deck logs, on clear days when the daily air temperatures in the shade did not exceed 66°F., were usually about 48°F., with a daily range between 10 a.m. and 4 p.m. of 72° to 112° for the upper surfaces and 58° to 64° for the lower surfaces. At the same time similar maximum differences of only 15°F., with a daily range of 57° to 72° for the upper surfaces and 50° to 56° for the lower surfaces of the woods deck logs, were found. These data suggest that, due to their warmer environment, the borers in the bark of the more exposed surfaces completed development and emerged 4 to 5 weeks earlier than did those in the more protected parts. They apparently had resumed activity earlier and had developed to adulthood with greater rapidity.

Theoretically the application of this information lies in the salvaging of borer-infested timber. Most of the early beetle emergence may be prevented by placing the logs in mill or storage ponds before the end of May. (Fig. 2B.) When this is not possible, the duration of the larval period can be extended by decking the logs under dense shade conditions. Much of the beetle emergence will then occur so late in the summer that the succeeding generation will have a 2-year life cycle. Under ideal conditions, these procedures should aid in materially limiting the beetle population and reducing the future infestation.

The log deck study also gave information on borer development at various heights on the tree trunk. With the exception of tree number 6, from which one beetle emerged - from a "B" log - there was more beetle emergence from the lower ("A") log than from the upper ("B") log. This suggests that probably the conditions of the dying tree made possible earlier successful attack on the lower portion of the bole and that a more favorable environment may have caused more rapid development. This seems probable in the light of the information gained from the root-condition study of similar trees. An examination of cross-sections from the trunks of these trees showed that the lower portion of the bole had failed to lay on wood and was apparently in a weaker, near-dying condition 1 year and 2 years before the upper portion ceased to lay on wood. Thus it seems probable that there may have been sufficient difference between the condition of the "A" and "B" logs for successful attack to have occurred earlier on the former, thus explaining why there was a greater total beetle emergence from the "A" logs regardless of their location - in the open or in the shade.

Trees number 2 and 6 were selected for the purpose of studying temperature effects on late 1938 ovipositions. Both contained heavy populations of very small larvae, about one-quarter grown, in May. These reached maturity in early August under the open log conditions, but as shown in table 1, no beetles emerged except a few which developed from occasional attacks earlier in 1938. Living larvae were found on the upper surfaces of both these logs when sampled in August and September. This indicated the high heat tolerance of the larvae since maximum subcortical temperatures of 110° F. had been measured as early as June 6 when the accompanying air temperature in the shade was 88° F. During late July and occasionally in August the temperature in the shade was 90° F. or above, and subcortical temperatures above 110° F. undoubtedly occurred.

Beetle Flight Period

This season's beetle flight on the reservation began about May 22 and continued through August. Between May 18 and 22, 16 beetles emerged from logs in the open deck. Beetle emergence from the logs of other open decks on the reservation and from the more exposed trees in very open stands began about the same date. On May 24, after considerable search, 2 beetles were found in the very open and heavily infested stands in the Camp 24 area. Beetles were abundant in this area by May 29. The peak of the beetle emergence in these very open stands occurred in early June; in the dense stands the emergence did not reach its peak until July. Occasional emergences were recorded until the end of August, and the last beetle was collected in the field on August 27.

Oviposition Habits

Apparently a period of a few days is required following emergence of the females for the maturation of the eggs. Newly emerged females

and females which had not been confined in their cages for more than 2 days following emergence were dissected for the purpose of obtaining records on the biotic potential. Their eggs were found to be immature, colorless, and very difficult to count. The mature eggs of beetles collected while ovipositing were slightly oval-shaped, white, could be seen with the naked eye, and were relatively easy to separate and count. By actual measurement the mature eggs measure o.85 x 0.70 mm. Additional study should be made in 1940 to determine the length of this period of egg development.

Sex Ratio of the Daily Beetle Migration to Trees

In two days of field collecting by a three-man crew, 1,200 beetles were taken. These were collected primarily to be used to insure borer oviposition on the girdled and check trees in the tree-condition study. Beetles were caged according to the hour of the day they were collected. A tally was kept of sex, and no great difference was found in the ratio for the entire day. This is in agreement with the observations made in 1938. However, on moderately cool days, during the first hour or two of collecting the number of males frequently exceeded the number of females by about 20 percent. In the late forenoon collections the sexes were about equal. The afternoon collections, when the temperatures were high, usually contained a decidedly greater number of females, but this was probably because the males were more active and more difficult to collect and not because of any change in the sex ratio. Counts made of caged material previously had indicated that the sex ratio was approximately 1 to 1.

Elytral Markings

All the beetles collected for the sex ratio study were also examined for the purpose of determining the prevalence of the spots on the elytra. These colored spots are responsible for the specific name fulvoguttata (reddish-yellow spotted). Dr. S. A. Graham, at the time of his visit to the reservation in July, had mentioned the possibility of there being more than one species present, and while this possibility still remains, it is believed that only one species is present. A tally was kept of the markings of 1,200 beetles. The majority of these beetles had either 3 pairs of spots (3 spots on each elytron) or no spots at all, although some instances of 1 and 2 pairs of spots were found. No attempt was made to group the beetles according to the number of spots, but they were recorded as having prominent, faint, or no spotting. Of this group, 38 percent had prominent spotting, 25 percent had faint spotting, and 37 percent, or, roughly, a third of the 1,200 beetles, had no elytral spots.

Parasites

The activity of Atanycolus sp. began shortly before May 17 and continued into September. They were very abundant during the early half of June and showed a noticeable increase over the numbers present in 1938. The last field collection was made on September 2. Emergences from caged material, however, were common in August, and two were found on September 12. Data on the length of thepupal period of Atanycolus sp. were obtained by periodically observing material kept under semi-humid conditions. Two parasite larvae, which were in newly spun transparent cocoons when collected July 1, emerged July 28 and 29 respectively,

thus requiring at least 4 weeks in the cocoon before adult emergence. The prepupal skin was shed between July 14 and 16. The white pupae appeared to be slightly colored about a week before the adults emerged and were noticeably pigmented the last 5 days. Both specimens were female, and their abdomens were enlarged and of a pinkish color when they emerged. In about 24 hours the characteristic reddish color was attained.

Odontaulacus bilobatus (Prov.) was first observed emerging on June 27, and the peak of emergence occurred near the close of the month. This species has a much shorter season than has Atanycolus sp. Emergence from caged material continued throughout July. On August 5 the last living specimen observed for the season was removed from one of the cages. It apparently had emerged during the week preceding that date.

In 1939 the following additional species were added to the list of known hemlock borer parasites collected during the course of this study: Deuteroxorides borealis (Cress.), Odontomerus canadensis (Prov.), a new species of Spathius, and a new species of Ichneumon. Cultural studies definitely proved the first and third of these to be true parasites. The second and fourth species were obtained from borer-infested material, and although it is very probable they are primary parasites, it is believed further study next season will confirm this.

The parasite population in this area is showing an upward trend. A brief survey was made in the camp 29 area during the last week in August by following the logging crews in a salvage operation. By doing this it was possible to obtain bark samples at 16-foot intervals

after the trees were felled, thus getting a more representative selection. These samples were about 1 foot square. A detailed tally was kept, for each sample, of the borer population, the parasite population, size of the bark area sampled, and the condition of the cambium. In addition notes were taken on the condition of the foliage and the ring growth. The borer population was taken by counting the number of emergence holes and adding the number of mature larvae in the bark. The parasite population was determined by counting the number of cocoons. On 115.6 square feet of bark chipped from 16 trees with mature borer populations, 584 beetles and mature larvae had survived, while 720 had been killed by parasites. Thus 51.4 percent of the borer population which had reached the wood and made galleries had been successfully parasitized. The borer population on this reservation is so heavy, however, that up to the present time parasites have not caused any noticeable reduction. The parasitization of the larvae having a 2-year life cycle is generally much heavier than that of those with a 1-year cycle. This apparently is due to the fact that the larger, second-season larvae are more readily found by the ovipositing female parasites than are the newly hatched larvae of the current season.

PHYSIOLOGICAL STUDIES

Susceptibility of Various Tree Conditions to Attack

A. Root-Condition Study: The hemlock root-condition study clearly demonstrated that the hemlock borer is a secondary insect. The root systems of 27 trees, representing various degrees of borer attack, were exposed by washing away the soil by means of hydraulic power. (Fig. 3A.) Borer attack had been successful only on trees which

were in a dead or dying condition at the time of attack. A separate detailed report covering this study, entitled "The Causes of the Decadence of Hemlock at the Menominee Indian Reservation, Shawano County, Wisconsin," has been prepared in joint authorship with H. J. MacAloney and R. C. Lorenz, the latter of the Bureau of Plant Industry. This paper has been submitted for approval for publication in the Journal of Forestry.

B. Attacks on Cut, Girdled, and Check Trees: Observations were continued on a series of 27 trees which in June 1938 were cut, half-girdled, or left as check trees. Field-collected beetles were placed in the cages on these trees at that time to insure borer oviposition. The attacks resulting from these ovipositions were successful only on the cut trees. (Fig. 3B.) Beetle emergence from these trees was first observed in the latter part of July and has been previously discussed under Length of Life Cycle. Since none of the attacks were successful on the check and half-girdled trees, field-collected beetles (30 females and 20 males) were placed in each cage on these trees in June 1939. This will also give information on the effect of repeated attack on vigorous and on weakened trees. Field-collected beetles were also placed in the cages of 6 additional trees which in 1939 were completely girdled except for about 6 inches of cambium. Three of the trees were girdled only to the sapwood, while the others were girdled about 1 inch into the heartwood.

C. Ring Growth Study: Examinations of cross-sections taken at intervals throughout the length of the boles of the 27 trees of the root-condition study, and blocks taken from some of the dying and recently dead trees in the 56 sample plots showed that most of these

trees had not laid on wood on the lower part of their boles for from 2 to 5 years. Figure 4 shows a block cut at a height of 56 feet from the trunk of one of the recently dead trees. The last of the foliage had fallen from this tree in the spring of 1938. The block was sectioned at an angle of about 30° in order to magnify the width of the rings and make it easier to standardize the ring pattern. The 1937 ring was the last laid on at the top of this tree; the rings at the base were very narrow in 1933 and 1934, and a partial 1935 ring was the last laid on the lower part of the bole. The cross-sections of 8 of the trees in the root-condition study, taken at intervals of 17 feet were measured along 4 radii (north, south, east, and west). The averaged measurements at different heights for 3 trees successfully attacked by borers (group I) are compared in table 2 with the measurements from 3 check trees without attacks (group II). The mean annual radial increment was determined for 4-year periods from 1923 through 1933. These figures indicate the gradual weakening of the group I trees during the drought period and explains, in part at least, why the borers were able to attack them successfully in 1938 and 1939.

Figure 5A shows a block from the base of a tree which lost its foliage in 1937 or 1938. The last ring laid on the lower part of the bole was in 1935, when spring wood, but no summer wood, was laid on. A block taken at a height of 52 feet on the same tree shows the 1936 ring. (Fig. 5B.) A partial 1937 ring was also laid on at the top, but it was so extremely narrow that it could be seen only with the aid of a hand lens and does not show in the photograph.

Sections taken from the main roots of some of the decadent trees in the sample plots showed that in many cases there was a difference of one and at times two rings between the roots and the trunk at a height of 4 feet above ground. This information substantiates the findings in the root condition study which indicated that under drought conditions the roots of the hemlock trees died before the foliage, and that death of the roots apparently was due to starvation.

Characteristics Identifying Dying Hemlocks

A series of characteristics have been found by which it appears possible to select trees that are going to die within the next two years. These are: (1) Thinning of the foliage, particularly at the terminal portions of the branches of the upper third of the crown. (Fig. 6.) (2) The presence of numerous unsuccessful attack galleries in the cambium tissues, indicating the low vigor of the tree. (3) Slow radial ring growth, showing a partial 1938 ring and no 1939 ring, or an absence of both. (4) General yellowish green foliage color. This usually is not noticeable until 6 months to a year before the foliage drops. The second and third characteristics are used merely to verify the suspicions raised by the first. When very pronounced, the fourth characteristic indicates that the tree is dead.

Using this sytem of selection, a 40-acre area was marked for cutting in the fall of 1939. This area will serve as a check as it will be re-examined in 1940. These characteristics were pointed out to the forest supervisor of the reservation, who, after repeated checking, was so convinced of their value that he has incorporated them in the

marking system and instructed the timber marking crew accordingly.

SAMPLE PLOT STUDIES

Procedure

All of the permanent hemlock sample plots on the reservation were examined in September to determine the 1939 mortality. There are 63 plots in all, eight $\frac{1}{4}$-acre growth study plots established by the Indian Service in 1929, and 55 $\frac{1}{5}$-acre plots, 49 established by Dr. Yeager in 1937 and 6 by the writer in 1938. The crown classes of many of the trees in these plots have changed since the plots were established because of the death of neighboring trees, and therefore the living trees were all reclassified in 1939, and a codominant class included. Previously there were three groups - dominant, intermediate, and suppressed.

As a part of the permanent records for each sample plot, two increment cores were taken from six selected trees - three dominant and three codominant. The average diameter at breast height was determined for the trees in the dominant and codominant classes and cores were removed from the north and south sides of the three trees nearest this average. These cores are mounted in rubber cement in corrugated-board files, and, together with the cores removed from all classes of trees in 1938, constitute a permanent part of the plot records. They have been measured to the nearest hundredth of a millimeter in a special increment core measurer; the increment since 1900 was measured and the annual and total increment since that time will be discussed in the section concerning the relationship between growth and precipitation.

Tree Mortality

The average gross volume for the hemlock type in the reservation is about 15,000 board feet per acre. For 32 plots in stands which have never suffered noticeable blowdown damage, the 1939 hemlock mortality by volume averaged 886 board feet per acre - 5.9 percent of the volume of the average stand. This is 43.5 percent of the volume (2,033 board feet) of trees which died in 1938. The mortality of hemlock in the plots in the areas damaged by blowdowns was 1,183 board feet per acre, and while this represents 36 percent of the volume (3,291 board feet) which died in 1938, the stocking of these areas is only about one-half that of the hemlock types so that actually the mortality (approximately 16 percent) is greater.

The plots in the blowdown areas have also suffered injury from exposure during the drought years and, because of changes in site conditions following blowdowns, are recovering very slowly. In extreme cases the forest conditions have been so altered that practically all of the hemlock and much of the birch have died. Fortunately such areas are few.

The noticeable decrease in mortality in 1939 indicates that the critical point created by the drought years has been passed. This is substantiated by the fact that dying trees which were losing their foliage for the first time in 1939 usually had not laid on any wood on their lower bole in 1937 or in the spring of 1938. Since trees that were not fatally injured until the last of the drought period lost their foliage and revealed their dying condition in 1939, it is reasonable to assume that most of the remaining green trees have recovered from the drought injury and that, with a continuance of favorable growing conditions, the mortality of trees in all but the severely

injured areas will soon return to normal.

Study of the 12 plots in the severely injured areas indicates that 71.4 percent of the dead and dying trees under 9 inches d.b.h., though overtopped when the plots were established in 1937, are now receiving direct sunlight equivalent to that of trees in the intermediate or higher crown classes. Similarly 47.4 percent of the trees of 9 inches d.b.h. and over, which were intermediate or suppressed in 1937, occupied a position in the stand of 1939 which was one or two classes higher than their former rank. These trees had a gross scale of only 1,720 board feet, or about 24.2 percent of the total volume of the dead hemlock trees. Thus their changed position in the forest cover was not due to growth but to the death and subsequent salvage or decay of the upper story trees. These data are presented in detail to show that there is evidence that exposure may be a prominent factor in the continuation of mortality among the smaller and weaker understory trees in those areas which have been severely injured and opened up by the death of trees which were in the overstory. In the 32 plots considered in table 2 there were only 8 trees for which exposure following release might have been a factor causing death. With the exception of one suppressed tree, all of these had been intermediate in 1937, and it is very improbable that exposure alone could have caused death. Thus it would appear that exposure is a negligible factor in areas where good forest conditions still prevail.

Relation of Growth Response to Precipitation

The average annual increment for 40 of the sample plot cores was calculated for each year of the 20-year period 1920 through 1939. These cores were from 20 dominant trees in 10 permanent sample plots

in different parts of the reservation where noticeable blowdown damage had not occurred during the past decade. The average radial increment for each year of the 1920-39 period was then compared with the annual average for this period and their departures calculated.

The precipitation records for the three Weather Bureau stations nearest the reservation (Antigo, Shawano, and Wausau) have been studied. Records for Shawano are not available earlier than June 1923, but those for Antigo and Wausau are available back to 1920. The average total precipitation was determined on an October to October basis and January to January basis for each year. The precipitation for the growing season, April through August, together with the departure from normal, was also determined. The departures from normal for both tree growth and precipitation were reduced to a common basis for sake of comparison. When tree growth was compared with precipitation of the current season, no correlation was found. There was a correlation, however, between tree growth and the annual precipitation of the preceding year plus a correction factor based on the spring precipitation of the current growing season. This correlation between hemlock growth and annual precipitation of the preceding year, rather than with that of the current season, agrees with the data presented in a report by McIntyre and Schnur on the effect of drought in oak forests.[1]

EFFECT OF EXPOSURE

Two 1-acre plots were established in October to study the effect of exposure on the residual stand following heavy logging. Fifty percent

[1] McIntyre, A. C. and Schnur, G. L. 1936. Effects of Drought in Oak Forests. Pa. Agr. Expt. Sta. Bul. 325

of the gross volume of these plots was removed in November under ordinary logging conditions. Actual scale showed a gross volume of 9030 board feet on one plot and 5040 board feet on the other. The ground around some of these trees will be left exposed to the sun so as to make conditions most favorable for heavy borer-attack. The remaining trees will be treated in the spring of 1940 by placing a layer of leaf mold or litter over their root systems so as to protect them from marked changes in soil temperature and moisture content.

Additional 1-acre plots are to be established in 1940 in some of the 10-acre experimental cutting areas of the Forestry Department of the Indian Service.

SUMMARY

1. The winter mortality of the hemlock borer during the winter of 1938-39 was from 5 to 10 percent.
2. The hemlock borer may have either a 1-year or 2-year life cycle depending on the condition of the cambium of the host and the time at which oviposition occurred. The life cycle is 1 year for early summer ovispositions on material that provides a favorable environment, and 2 years for late summer (August) ovipositions on similar material. Under less favorable environmental conditions July ovipositions may have a 2-year cycle although the 1-year cycle is the rule.

3. A study of the effect of temperature on the initiation of pupation and the time of beetle emergence was made. There may be a difference of 4 to 5 weeks between the peaks of beetle emergence from the upper and lower surfaces of the same log decked in the open; the peaks of emergence from these surfaces in the shade will have a difference of 2 to 3 weeks. The peaks for both upper and lower surfaces of the logs in the shade were 2 to 4 weeks later than those for corresponding surfaces in the open. This would indicate that when it is necessary to leave infested logs in the woods during May they should be decked in the shade. This will lengthen the larval period and prevent emergence of beetles until the logs can be placed in water. When storage ponds are not available it is theoretically possible to cause a 2-year cycle by decking the logs in dense shade. These logs could then be utilized before the beetles emerge the second year.

4. There is evidence indicating that the hemlock borer larvae can resist high sub-cortical temberatures. Larvae were found to have survived temperatures of 110° F. without apparent increase in mortality.

5. The 1939 beetle flight on the Menominee Indian Reservation began about May 22 and continued through August. The greatest amount of activity occurred during June.

6. A study of the sex ratio in the daily beetle migration to the trees to oviposit showed that both sexes were equally represented.

7. The elytral markings of 1,200 field collected beetles were noted. In about 38 percent of the beetles spots were prominent, in 25 percent they were faint, and in 37 percent they were absent.

8. The activity of Atanycolus sp. began shortly before May 17, and continued into September. The pupal period for this species is 4 weeks. Odontaulacus bilobatus (Prov.) became active during the first week of June and continued active to early August. Four additional species of parasites of the hemlock borer were collected in 1939.

9. The parasite population in the stands on the reservation is showing an upward trend. A brief survey showed a parasitization of 51 percent. No noticeable reduction in beetle population is as yet apparent.

10. Parasitization of the larvae having a 2-year cycle is generally heavier than for the 1-year cycle.

11. The hemlock root-condition study clearly indicated that the hemlock borer is a secondary insect under these conditions. The borers are able to attack successfully only trees which are in a dead or dying condition.

12. A series of experimental trees were cut, half-girdled, or left as check trees in 1938. Borer attacks were successful only on the cut trees, and beetles emerged in 1939. The half-girdled and check trees were reinfested in 1939 to study the effect of repeated attacks on vigorous and weak trees.

13. Examinations of cross-sections from trees in the root-condition study and of blocks and cores from some of the dying and recently dead trees in the sample plots showed that most of the dead and dying trees had not laid on wood on the lower part of the boles during the past 2 to 5 years. A difference of 2 to 3 rings was also usually found between the upper and lower portions of the boles of the trees of the root-condition study.

14. The 1939 tree mortality was noticeably less than that of the previous year. In 32 plots in stands which have never suffered noticeable blowdown damage the 1939 mortality was 5.9 percent of the stand volume compared to 16 percent in 1938. In 12 plots in the blowdown-injured areas the 1939 mortality was 8.2 percent compared with 23.7 percent in 1938.

15. A brief study of the relationship of tree growth response to precipitation indicated that there was no correlation when growth was compared with the precipitation of the current season.

There is a relation, however, when growth was compared to the precipitation of the previous season. This correlation was more evident when a corrective factor, based on the spring precipitation of the previous year, was applied.

16. Studies of the effect of exposure on the residual stand following heavy logging were initiated in the fall of 1939. Two 1-acre sample plots were established in October, and 50 percent of the gross volume was removed. Additional 1-acre plots may be established in 1940 in some of the 10-acre experimental cutting plots of the forestry department at the reservation.

Table 1.- Difference in amount of beetle emergence, by dates, from upper and lower surfaces of logs in open and shaded decks

D E C K   I N   O P E N

LOG No.	SURFACE of LOG	MAY 22	MAY 26	JUNE 2	JUNE 9	JUNE 17	JUNE 30	JULY 10	JULY 17	JULY 31	AUGUST 11	AUGUST 22	AUGUST 30
1B	Upper	0	0	0	0	0	0	0	0	1	0	0	0
	Lower		0	0	0	0	0	0	0	0	0	0	0
2A	Upper	1	1	0	0	0	1	0	0	0	0	0	0
	Lower		0	0	0	0	0	0	0	0	0	0	0
3B	Upper	0	0	0	0	0	0	0	0	0	0	0	0
	Lower		0	1*	0	0	5	1	0	3*	0	0	0
4A	Upper	5	6	0	4*	1*	1*	1*	0	0	0	0	0
	Lower		0	11*	0	1	1	7	10	8	0	2	0
5 B	Upper	0	0	0	0	0	0	0	0	0	0	0	0
	Lower		0	0	0	0	0	0	0	0	0	1	0
6A	Upper	0	0	0	0	0	0	0	0	0	0	0	0
	Lower		0	0	0	0	0	0	0	0	0	0	0
7B	Upper	6	16	3	4*	4*	0	0	0	0	0	0	0
	Lower		2*	0	1	8	14	7	3	8	3	0	0
8A	Upper	4	13	3	8	3	5*	0	0	1*	0	2*	0
	Lower		3	0	0	1	16	27	11	12	0	0	0
TOTAL	Upper	16	36	6	16	8	7	1	0	2	0	3	0
	Lower		5	12	1	10	36	42	24	24	3	3	0

D E C K   I N   S H A D E

LOG NO.	SURFACE of LOG	MAY 22	MAY 26	JUNE 2	JUNE 9	JUNE 19	JUNE 30	JULY 10	JULY 19	JULY 31	AUGUST 11	AUGUST 22	AUGUST 30
1A	Upper	0	0	0	2	0	4	2	2	4	0	0	0
	Lower		0	0	0	0	0	0	4	4	0	0	0
2B	Upper	0	0	0	0	0	1	0	0	0	0	0	0
	Lower		0	0	0	0	0	0	0	0	0	0	0
3A	Upper	0	0	0	19	5	21	12	3	1	0	0	0
	Lower		0	0	1*	0	0	16	6	5	3	1	3
4B	Upper	0	0	0	5	0	15	13	2	2	0	0	0
	Lower		0	0	0	0	0	1	2	5	2	0	3
5A	Upper	0	0	0	1	2	45	15	1	0	1	0	0
	Lower		0	0	0	0	0	9	3	3	0	0	0
6B	Upper	0	0	0	0	0	0	0	0	0	0	0	0
	Lower		0	0	0	0	0	0	1	0	0	0	0
7A	Upper	0	0	0	1	0	17	4	1	0	0	0	1
	Lower		0	0	0	2*	0	2	11	6	1	0	2*
8B	Upper	0	0	0	0	0	3	3	0	0	0	0	0
	Lower		0	0	0	0	2	0	1	0	1	0	0
TOTAL	Upper	0	0	0	19	7	106	49	9	7	1	0	1
	Lower		0	0	1	2	2	26	30	25	7	1	8

Underlined sections indicate peaks of emergence.
* Practically all of these beetles emerged from the bark on the sides of the logs.

Table 2.-- Comparison of increment, in hundredths of millimeters, of 3 trees showing successful borer attack in 1938 and 1939(Group I) with that of 3 trees with no borer attack(Group II). Based on the average of 4 radial measurements at intervals of 17 feet on each tree.

GROUP I						GROUP II					
		Increment in hundredths of millimeters						Increment in hundredths of millimeters			
Disk No.	Height above Ground in ft.	1938 to 1935	1934 to 1931	1930 to 1927	1926 to 1923	Disk No.	Height above Ground in ft.	1938 to 1935	1934 to 1931	1930 to 1927	1926 to 1923
1	3	46.1	71.5	142.4	131.2	1	3	[illegible].4	65.2	107.3	110.0
2	20	41.2	52.7	104.6	88.5	2	20	69.9	51.8	79.0	76.3
3	37	59.1	68.8	109.1	87.9	3	37	88.6	68.6	101.7	93.7
4	54	70.4	74.7	95.6	99.8	4	54	95.8	56.4	100.0	94.4
5	71	73.2	72.6	104.1	88.9	5	71	119.8	98.7	115.7	75.1
6	88	32.4	32.6	47.0	50.1	6	88	26.3	40.4	63.7	77.0
TOTALS		322.4	372.9	602.8	546.4	TOTALS		464.6	389.1	567.4	526.5
Average		53.7	62.1	100.5	91.1	Average		77.4	64.8	94.6	87.8

Figure 1.- Beetle emergence from tree number 66 commenced in July 1939, completing a 1-year life cycle. By the close of the season 49 beetles had emerged from the 46-inch section of the log enclosed in the cage. The emergence holes of 33 of the beetles may be seen, against a white background, in the picture. This tree was successfully attacked for the first time after it was felled in June 1938.

Figure 2A.- Beetle emergence from the logs in this deck, which was under a dense forest cover, did not commence until 2 to 4 weeks after emergence had begun from logs in open decks.

Figure 2B.- Hemlock borer-infested logs in the mill pond of the Menominee Indian Mills, Neopit, Wisconsin.

Figure 3A.- The roots of 4 trees excavated in the root-condition study. A shovel, with a handle 6 feet long, may be seen to the left of the stump in the foreground.

Figure 3B.- The larval population of tree number 81 was mature and entering the bark when sample sections were peeled in October 1938. Beetle emergence from this tree began in July 1939.

Figure 4.- An examination of the annual rings of most of the trees which lost their foliage in 1939 showed that these trees had not laid on any wood on their lower bole in the last two years. The last ring in the section shown in the above picture was composed of 1937 spring wood only - no summer wood being laid on that year.

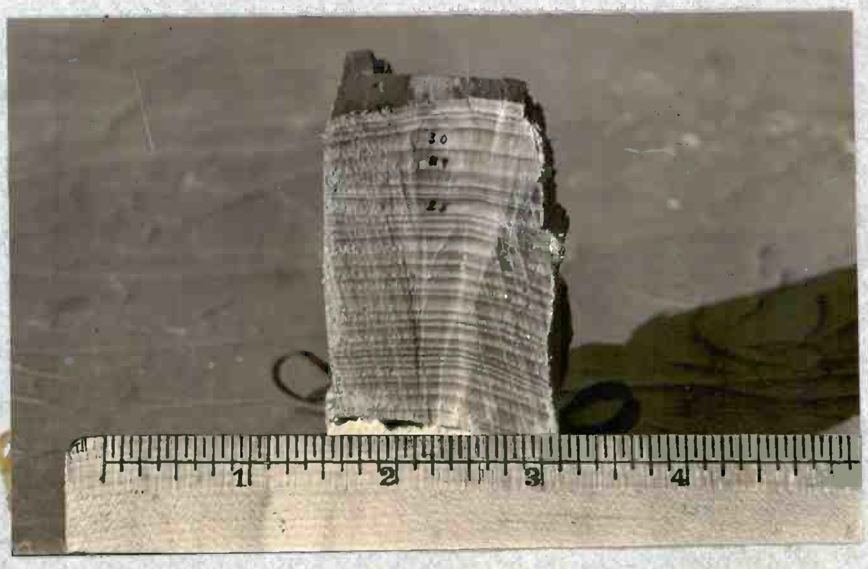

Figure 5A.- A block from the base of a tree on which the last ring on the lower bole was laid on in 1935. The foliage dropped in 1937 or 1938.

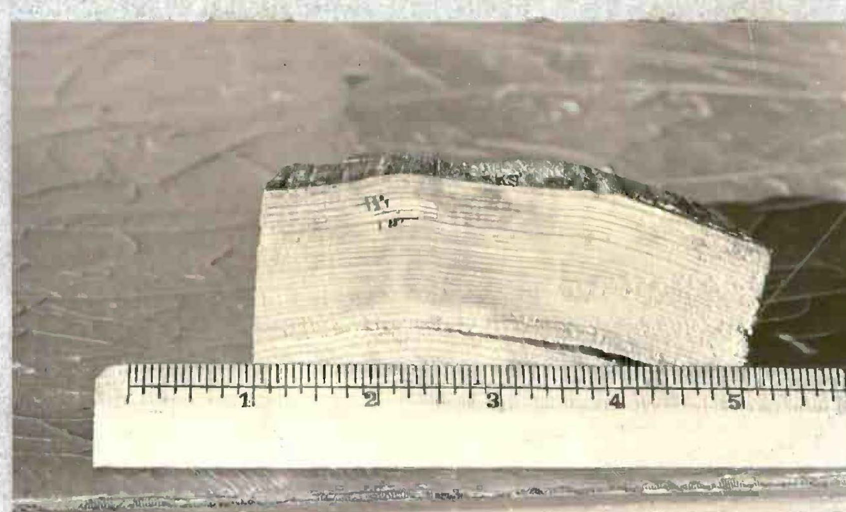

Figure 5B.- A block from the same tree at a height of 52 feet. The 1935 and 1936 rings may be seen in this picture with the aid of a hand lens. A very narrow ring of 1937 spring wood cannot, however, be detected.

Figure 6.- Thinning of the foliage, particularly at the tips of the branches, is usually the first indication of a dying hemlock. This condition may be noticed a year before the foliage shows a yellow color. This picture shows a tree, on the left, with normal foliage and one on the right with thin foliage. In the center is a dead tree from which all the foliage has fallen.